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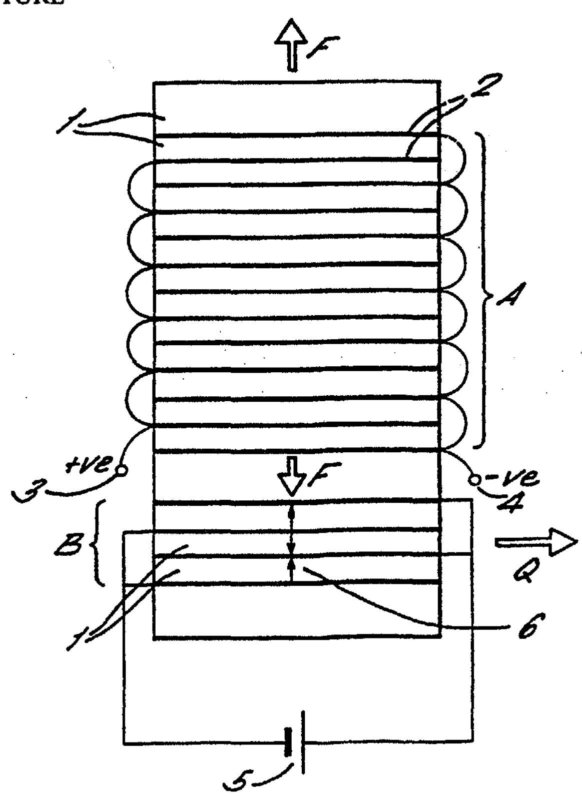
(54) Title: COMPOSITE MULTILAYER CERAMIC STRUCTURE

(57) Abstract

A composite multilayer ceramic structure which comprises in a single device a plurality of layers of an electrostrictive dielectric material separated by a plurality of electrode layers in which a first portion is adapted to operate as an electrostrictive actuator and a second portion, which is adjacent to the first portion and which is not inherently piezoelectric, is adapted to operate in the same way as a piezoelectric sensor.



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COMPOSITE MULTILAYER CERAMIC STRUCTURE

The present invention relates to a composite multilayer ceramic structure and, in particular, to a controlled force or force limited multilayer ceramic actuator which comprises a combination of an electrostrictive actuator and sensor.

Multilayer ceramic actuators in which a plurality of layers of a dielectric material are separated by a plurality of electrode layers are known in the art. We have now developed a composite multilayer ceramic structure in which a multilayer electrostrictive ceramic actuator is combined with a sensor in a single device.

Accordingly, the present invention provides a composite multilayer ceramic structure which comprises a plurality of layers of an electro-strictive dielectric material separated by a plurality of electrode layers in which a first portion is adapted to operate as an electrostrictive actuator and a second portion, which is adjacent to the first portion and which is not inherently piezoelectric, is adapted to operate in the same way as a piezoelectric sensor.

The composite multilayer ceramic structure of the present invention is a controlled force or force limited electrostrictive actuator which comprises a stack of a plurality of layers of an electrostrictive dielectric material separated by a plurality of electrode layers, alternate electrodes in a first portion of the stack being connected to positive or negative potential and means to apply a voltage thereto, alternate electrodes in a second portion of the stack being connected to positive or negative potential and means to apply a bias voltage thereto, means to measure the charge produced by the second

portion of the stack and means to adjust the voltage applied to the first portion of the stack.

In the composite multilayer structure of the present invention the second portion adapted to operate as a sensor may be sandwiched between first and third portions which are adapted to operate as electrostrictive actuators.

The first portion, and the third portion of the composite composite multilayer ceramic structure when present, are adapted to operate as electrostrictive actuators.

The material which is used as the electrostrictive dielectric material in the different portions of the structure may be the same or different, although it is preferred to use the same material. For example, the same dielectric material may be used for the different portions of the structure, providing that it is a material in which piezoelectricity can be induced, for example by the application of a bias field.

The present invention also includes within its scope a method of producing a controlled force or force limited multilayer ceramic actuator which comprises forming a stack of a plurality of layers of an electrostrictive dielectric material separated by a plurality of electrode layers, operating a first portion of the stack as an electrostrictive actuator by connecting alternate electrodes in the first portion of the stack to positive or negative potential and applying a voltage thereto, and inducing piezoelectricity in a second portion of the stack so that it generates a charge which is proportional to the force produced by the actuator.

The charge, Q, generated by the sensor portion of the structure may be measured by conventional techniques. Measurement of the charge enables the

force acting on the sensor portion of the structure to be determined and the force applied by the electrostrictive actuator may be controlled or limited by varying the voltage which is applied to the first (and optionally third) portion(s) of the stack.

The controlled force or force limited actuator of the present invention may be used in mechanised devices, such as precision robots.

The present invention will be further described with reference to the accompanying drawing in which:-

Figure 1 is a diagram of a multilayer ceramic structure in accordance with the invention which is formed from a single electrostrictive ceramic material; and

Figure 2 is a graph in which the output of the sensor portion of a device according to the invention is plotted as a function of the applied load.

Referring to Figure 1, the actuator comprises a plurality of layers of the same dielectric material 1 which are separated by a plurality of electrode layers 2. The structure, as shown, is essentially divided into two portions, the first portion A operating as an electrostrictive actuator whilst the second portion B acts as a piezoelectric sensor. Alternate electrodes in portion A are connected together to a positive potential 3 or a negative potential 4. A voltage is thereby applied to the electrostrictive portion A of the structure. The application of a voltage across the electrostrictive portion A of the structure produces strain and generates force which is indicated by the arrows F on the figure. The alternate electrodes of the portion of the structure B are connected to a bias voltage source 5 and a bias voltage applied thereto. The bias field induces piezoelectricity and induced

piezoelectric dipoles 6 are shown by the arrows in the Figure. The piezoelectric sensor portion B of the structure is thereby placed under stress and generates an electric charge Q which is measured by conventional means, not shown. Measurement of the charge Q enables determination of the force F acting on the piezoelectric sensor portion B of the structure, thus allowing the force applied by the actuator portion A of the structure to be controlled or limited by varying the voltage applied thereto.

Figure 2 is a graph in which the output of the sensor portion of a device as described with reference to Figure 1 was plotted as a function of the applied load. The sensor portion of the device comprised 10 layers, the thickness of the dielectric layers being 125 micrometres and the thickness of the electrode layers being 10 micrometres. The area of each layer of the device was 10 X 9 mm. The D.C. voltage (bias voltage) was 30 V.

The output signal is suitable for use in a standard feedback circuit, enabling the combined device to be used to control or limit the load which it applies.

CLAIMS:

1. A composite multilayer ceramic structure which comprises in a single device a plurality of layers of an electrostrictive dielectric material separated by a plurality of electrode layers in which a first portion is adapted to operate as an electrostrictive actuator and a second portion, which is adjacent to the first portion and which is not inherently piezoelectric, is adapted to operate in the same way as a piezoelectric sensor.

2. A composite multilayer ceramic structure as claimed in claim 1 wherein the second portion is positioned between first and third portions which are adapted to operate as electrostrictive actuators.

3. A composite multilayer ceramic structure as claimed in claim 1 or claim 2 wherein the same dielectric material is used in the first and second portions, and the third portion when present.

4. A composite multilayer ceramic structure as claimed in claim 1 or claim 2 wherein different electrostrictive dielectric materials are used for the first (and third) portion(s) adapted to operate as an electrostrictive actuator, and the second portion adapted to operate in the same way as a piezoelectric sensor.

6. A method of producing a controlled force or force limited multilayer ceramic electrostrictive actuator which comprises forming a stack of a plurality of layers of an electrostrictive dielectric material separated by a plurality of electrode

layers, operating a first portion of the stack as an electrostrictive actuator by connecting alternate electrodes in the first portion of the stack to positive or negative potential and applying a voltage thereto, and inducing piezoelectricity in a second portion of the stack so that it generates a charge which is proportional to the force produced by the actuator.

6. A method as claimed in claim 5 wherein the same dielectric material is used in the first and second portions of the stack.

7. A method as claimed in claim 5 or claim 6 wherein piezoelectricity is induced in the second portion of the stack by applying a bias field thereto.

8. A method as claimed in any one of claims 5 to 7 wherein the force applied by the electrostrictive actuator is controlled by varying the voltage which is applied to the first portion of the stack.

9. A controlled force or force limited multilayer ceramic electrostrictive actuator which comprises a stack of a plurality of layers of an electrostrictive dielectric material separated by a plurality of electrode layers, alternate electrodes in a first portion of the stack being connected to positive or negative potential and means to apply a voltage thereto, alternate electrodes is a second portion of the stack being connected to positive or negative potential and means to apply a bias voltage thereto, means to measure the charge produced by the second portion of the stack and means to adjust the voltage applied to the first portion of the stack.

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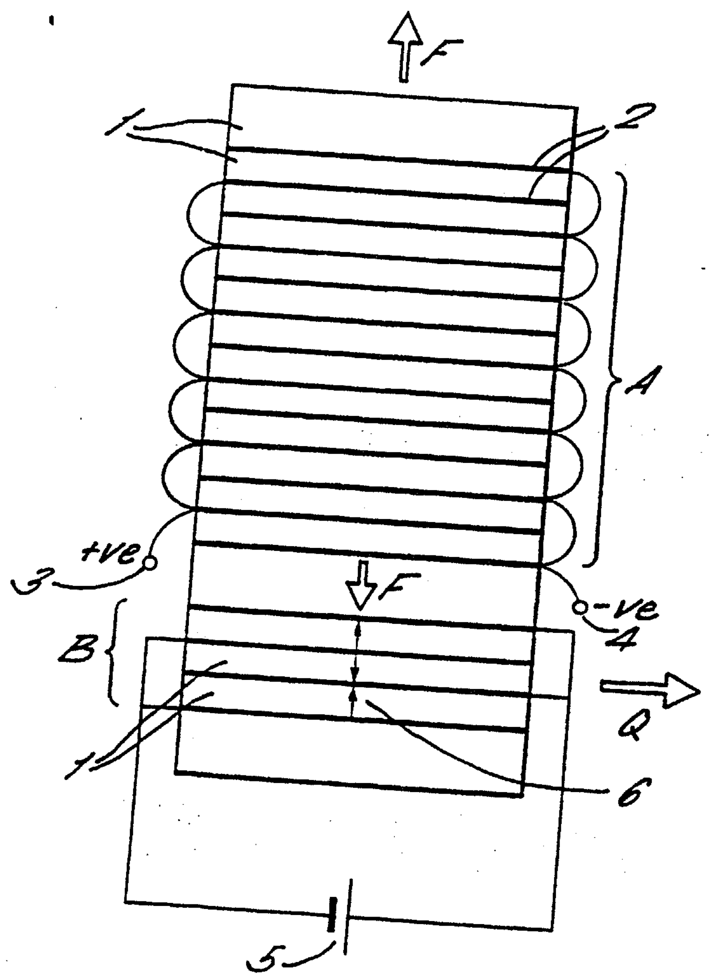
FIG. 1.



ANNEX TO THE INTERNATIONAL SEARCH REPORT ON INTERNATIONAL PATENT APPLICATION NO. PCT/GB 91/01674

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